Are we risking biosecurity for bioenergy? The potential for biofuels to become invasive weeds




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Policy Initiatives

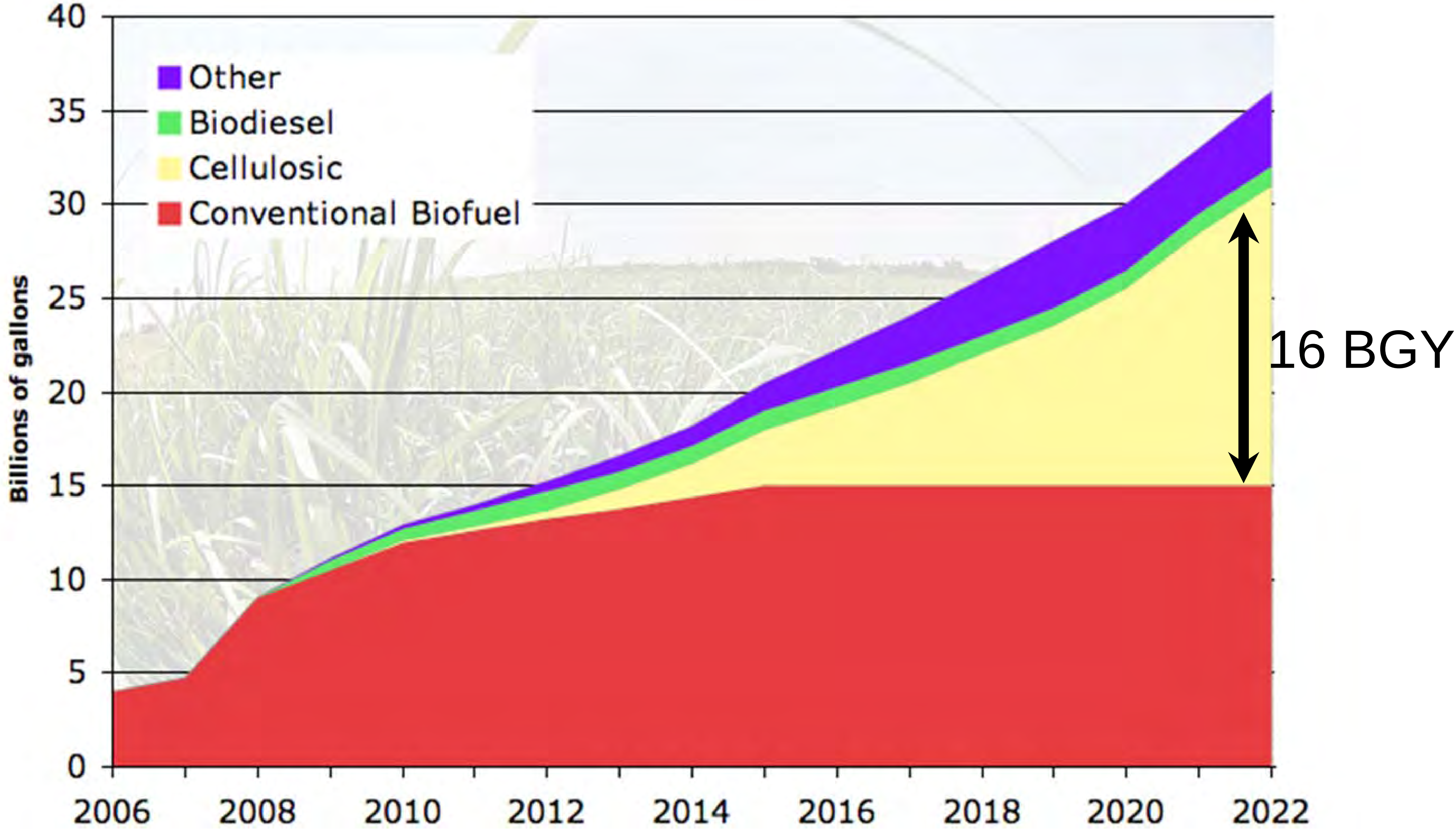
<u>Federal:</u>

- "20 in 10"
  - Reduce gasoline usage by 20% in 10 years
  - 35 billion gallons renewable/alternative fuels in 2017
- "30 by '30" = "Billion Ton Report"
  - Replace 30% of petroleum with biofuels by 2030
- **Energy Independence and Security Act (EISA)**
  - 36 billion gallons of renewable fuel by 2022

<u>California:</u>

- AB 32 "Global Warming Solutions Act"
  - Reduce GHG emissions to 1990 levels by 2020
- Executive Order S-06-06
  - 20% of electricity be biomass-derived by 2020
  - In-state biofuel production: 20% - 2010, 40% - 2020, 75% - 2050
- Executive Order S-01-07
  - Low Carbon Fuel Standard

Energy Independence and Security Act 2007



Food, Conservation, and Energy Act 2008

<u>Title IX: Sec. 9011: </u>*Biomass Crop Assistance Program*

Eligible crop does <u>not</u> include:

- "any plant that is invasive or noxious or has the potential to become invasive or noxious, as determined by the Secretary, in consultation with other appropriate Federal or State departments and agencies."

H.R. 2419-406

Biofuels and Invasives

Outlines similarities between agronomic traits of biofuels and invasive species.

"Experts must assess ecological risk before introducing biofuel crops, to ensure that we do not add biofuels to the already raging invasive species fire.'

Ideal agronomic characteristics

- **Life history**
  - Perennial
  - High aboveground biomass production
  - Flowers late / little allocation to seed production
- **Physiology**
  - Tolerates
    - Drought
    - Low fertility
    - Saline soils
  - C_4 photosynthetic pathway
  - High water/nutrient use efficiency
- **Other**
  - Highly competitive (reduces herbicide use)
  - Few resident pests (reduces pesticide use)
  - Allelopathic
  - Re-allocates nutrients to roots in fall

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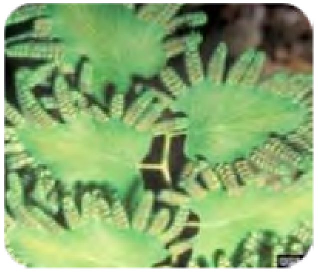
Origins of Invasive Plants

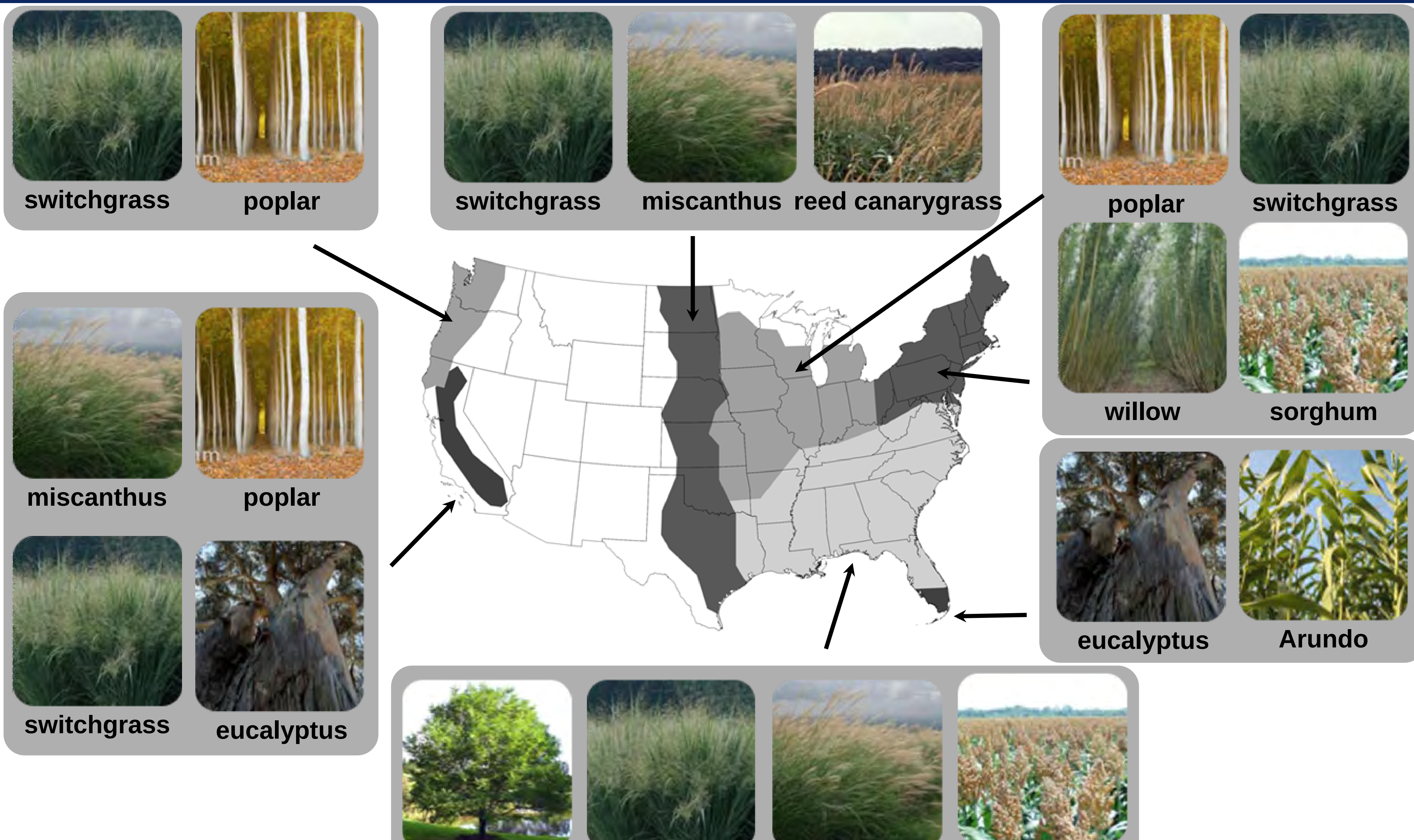
- 85% of invasive woody species from landscaping
- 63% of California-IPC's most invasive species have horticultural origin
- 69% of Florida-EPPC's list have horticultural origin

Invasive species with agronomic origin:

- Johnsongrass (*Sorghum halepense*)
- Kudzu (*Pueraria montana* var. *lobata*)

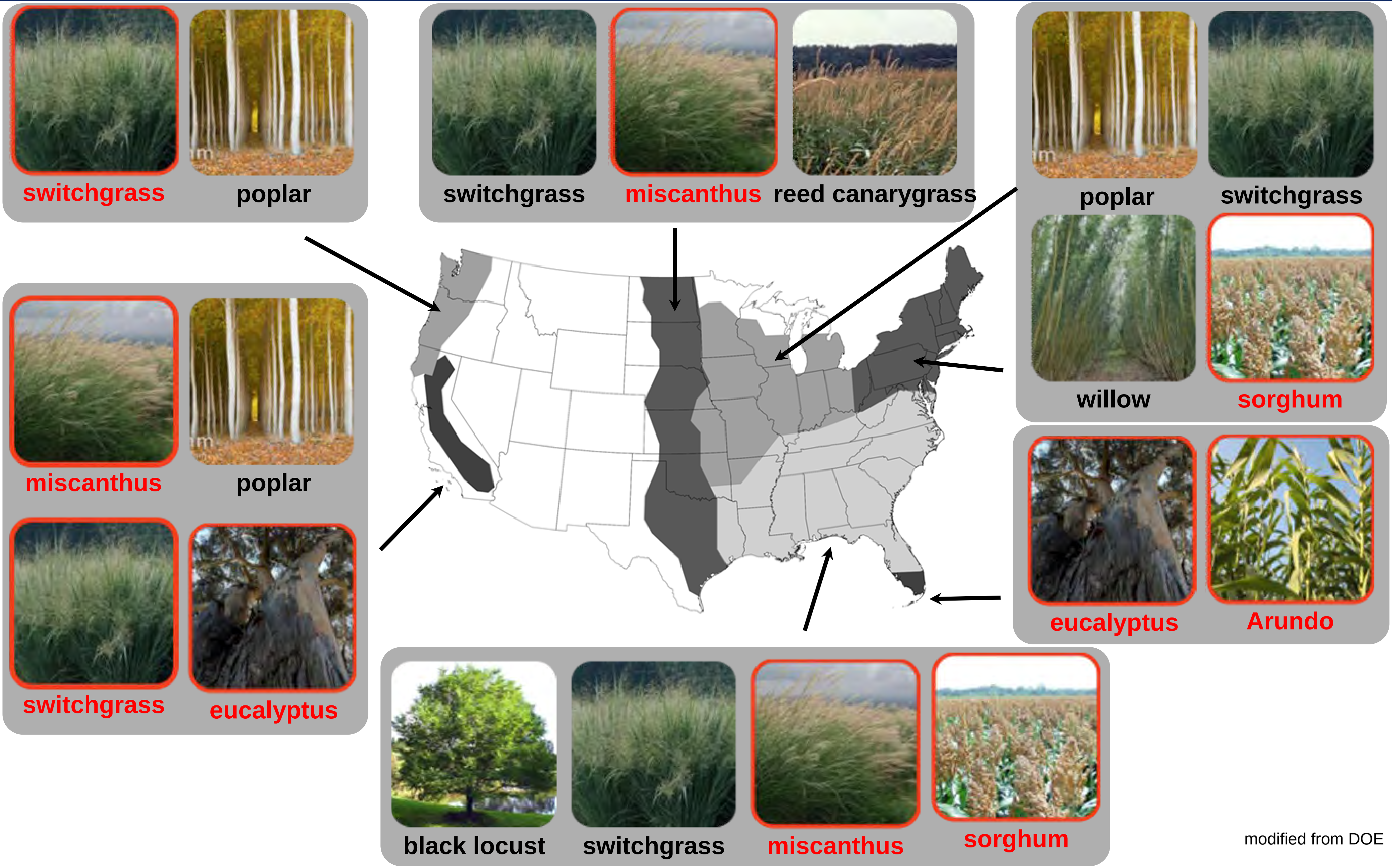


Cellulosic portfolio



modified from DOE

Cellulosic portfolio



modified from DOE

Why are we concerned?

- Arundo is a state listed noxious weed in California and Texas
- Switchgrass is on the California Dept Food Ag noxious weed list
- *Miscanthus sinensis* is a known invasive in the eastern US, *M. sacchariflorus* listed in MA: *M.* x *giganteus* parents
- Reed canarygrass state listed in WA, MA, CT

Why are we concerned with a “native” plant?

- *“Coevolution with native community members is not proof against unexpected damage”*

- Environmental change
- Genetic change
- Novel environments
- Hybridization

Simberloff 2008 Weed Science

Biofuel Feedstocks: The Risk of Future Invasions

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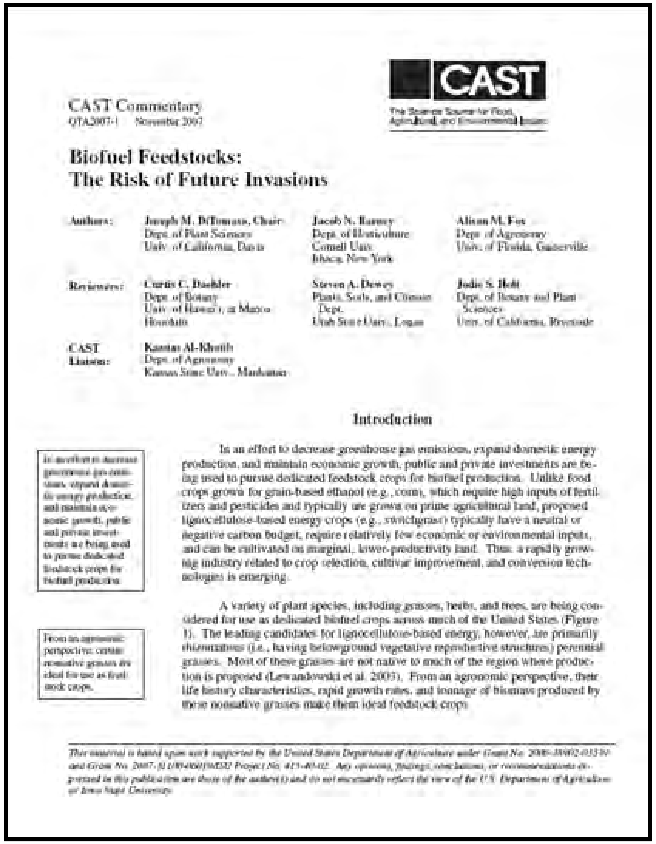
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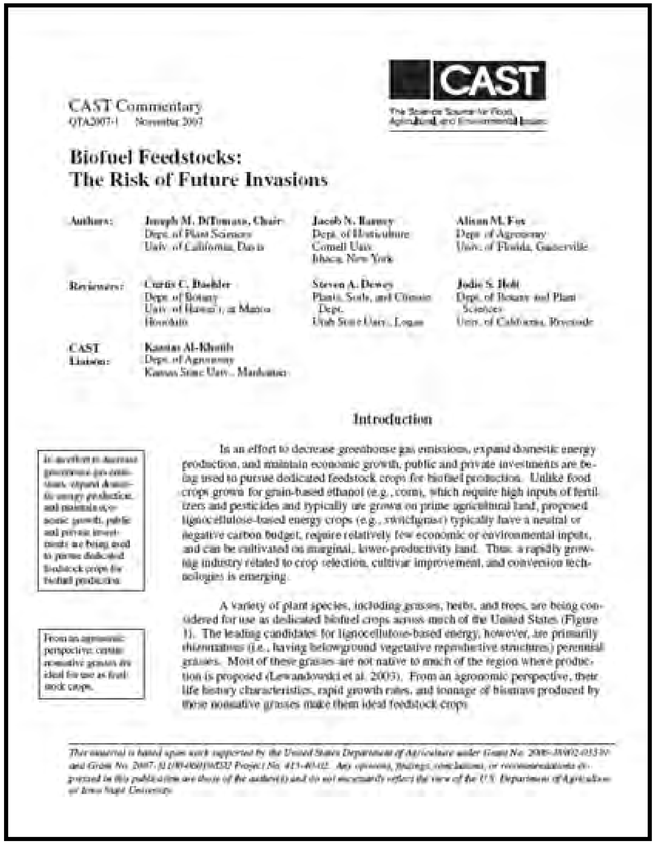
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Weed Risk Assessment

Pre-entry weed risk assessment

Protect | Get | Species | Help | Print repor
Run | Store | Update | Save

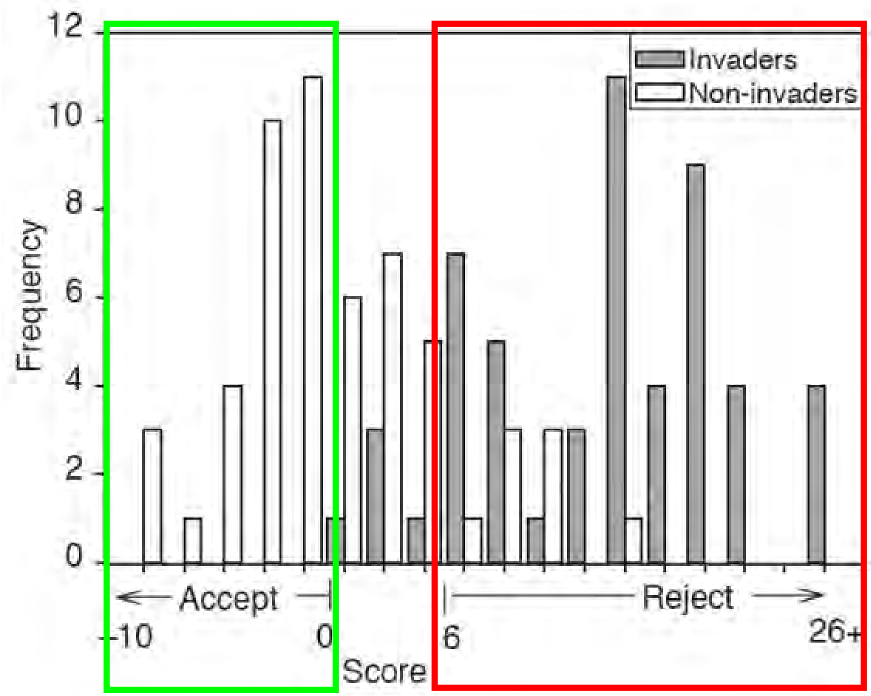
Outcome:	Evaluate
Score:	4
	Panicumvirgatum(species)
	switchgrass
	jnb

	A.	**Biogeography/ historical**			
C	1	*Domestication/ cultivation*	1.01	Is the species highly domesticated?	Y
C			1.02	Has the species become naturalised where grown?	N
C			1.03	Does the species have weedy races?	
-	2	*Climate and Distribution*	2.01	Species suited to Australian climates (0-low; 1-interm	
-			2.02	Quality of climate match data (0-low; 1-intermediate	
C			2.03	Broad climate suitability (environmental versatility)	
C			2.04	Native or naturalised in regions with extended dry pe	
-			2.05	Does the species have a history of repeated introduc range?	
C	3	*Weed Elsewhere (interacts with 2.01 to give a weighted score)*	3.01	Naturalised beyond native range	
N			3.02	Garden/amenity/disturbance weed	N
A			3.03	Weed of agriculture	N
E			3.04	Environmental weed	N
C			3.05	Congeneric weed	Y
-	B.	**Biology/Ecology**			
C	4	*Undesirable traits*	4.01	Produces spines, thorns or burrs	N
C			4.02	Allelopathic	
C			4.03	Parasitic	N
A			4.04	Unpalatable to grazing animals	N
C			4.05	Toxic to animals	N
C			4.06	Host for recognised pests and pathogens	
N			4.07	Causes allergies or is otherwise toxic to humans	
E			4.08	Creates a fire hazard in natural ecosystems	Y
E			4.09	Is a shade tolerant plant at some stage of its life cycle	Y
E			4.10	Grows on infertile soils	Y
E			4.11	Climbing or smothering growth habit	N
C			4.12	Forms dense thickets	Y
E	5	*Plant type*	5.01	Aquatic	N
C			5.02	Grass	Y
E			5.03	Nitrogen fixing woody plant	N
C			5.04	Geophyte	N
C	6	*Reproduction*	6.01	Evidence of substantial reproductive failure in native habitat	N
C			6.02	Produces viable seed.	Y
A			6.03	Hybridises naturally	
C			6.04	Self-compatible or apomictic	N
C			6.05	Requires specialist pollinators	N
A			6.06	Reproduction by vegetative fragmentation	Y
C			6.07	Minimum generative time (years)	1
A	7	*Dispersal mechanisms*	7.01	Propagules likely to be dispersed unintentionally (plants growing in heavily trafficked areas)	Y
C			7.02	Propagules dispersed intentionally by people	Y
A			7.03	Propagules likely to disperse as a produce contaminant	N
C			7.04	Propagules adapted to wind dispersal	N
E			7.05	Propagules water dispersed	Y
E			7.06	Propagules bird dispersed	
C			7.07	Propagules dispersed by other animals (externally)	N
C			7.08	Propagules survive passage through the gut	
C	8	*Persistance attributes*	8.01	Prolific seed production (>2000/m2)	Y
C			8.02	Evidence that a persistent propagule bank is formed (>1 yr)	Y
A			8.03	Well controlled by herbicides	
A			8.04	Tolerates, or benefits from, mutilation or cultivation	
C			8.05	Effective natural enemies present in Australia	
				Outcome:	Evaluate
				Score:	4

Statistical summary of scoring	Score partition:	Biogeography	-4
		Undesirable attributes	3
		Biology/ecology	5
	Questions answered:	Biogeography	10
		Undesirable attributes	9
		Biology/ecology	18
		Total	37
	Sector affected:	Agricultural	0
		Environmental	4
		Nuisance	0

A= agricultural, E = environmental, N = nuisance, C=combined

6	*Reproduction*	6.01	Evidence of substantial reproductive failure in native habitat	N
		6.02	Produces viable seed.	Y
		6.03	Hybridises naturally	



from Daehler et al. 2000

>90% accurate in identifying invasive species

Dedicated feedstocks

switchgrass
(Panicum virgatum)

miscanthus
(Miscanthus* x *giganteus)

giant reed
(Arundo donax)

Barney & DiTomaso 2008 *BioScience*

Weed Risk Assessment

Switchgrass - *Panicum virgatum*

California:

Standard WRA = **Reject**

Sterile = **Accept**

Giant Reed - *Arundo donax*

Florida:

Standard WRA = **Reject**

Miscanthus - *Miscanthus* x *giganteus*

Entire US:

Standard WRA = **Accept**

Barney & DiTomaso 2008 *BioScience*

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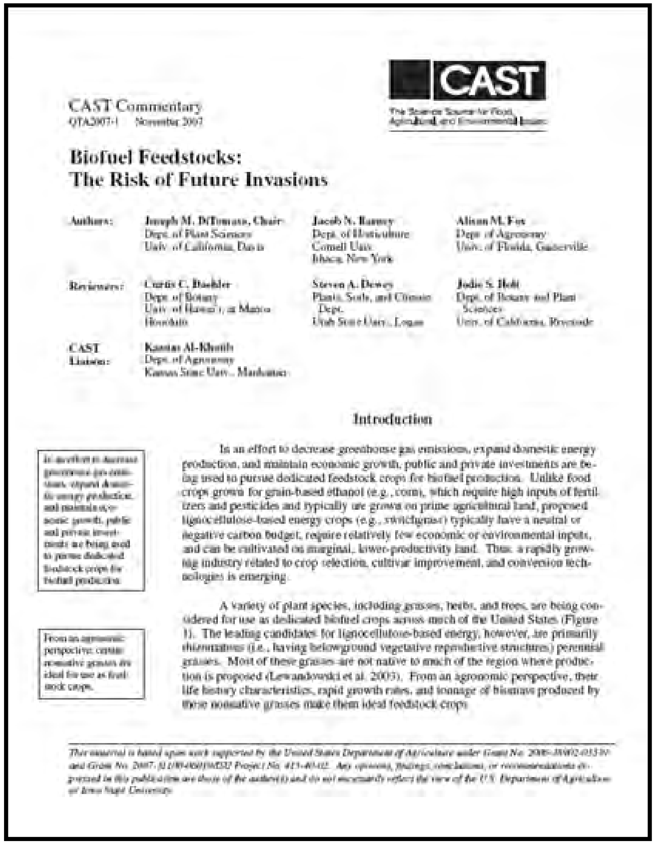

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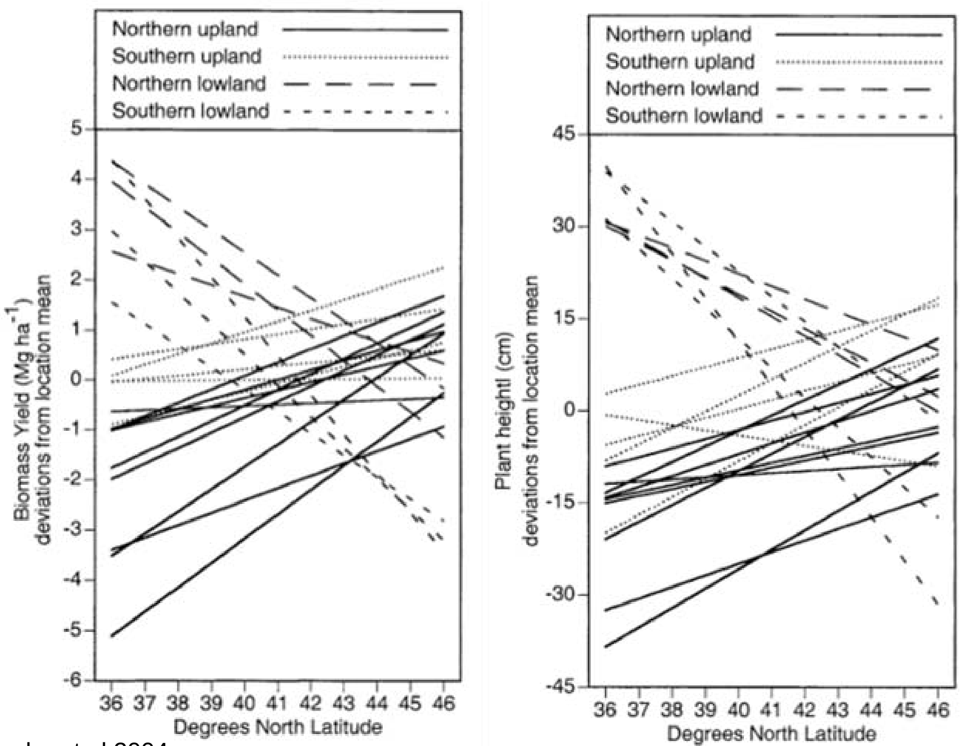
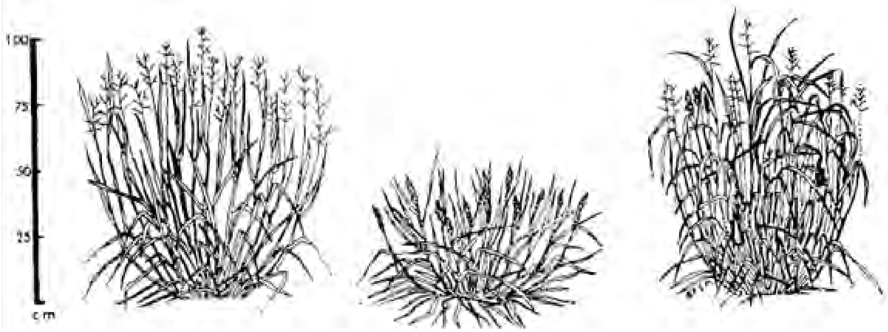
Switchgrass biology

- **2 ecotypes:**
  - **Upland** (octoploids): mesic - xeric
  - **Lowland** (tetraploids): hydric



Casler et al 2004

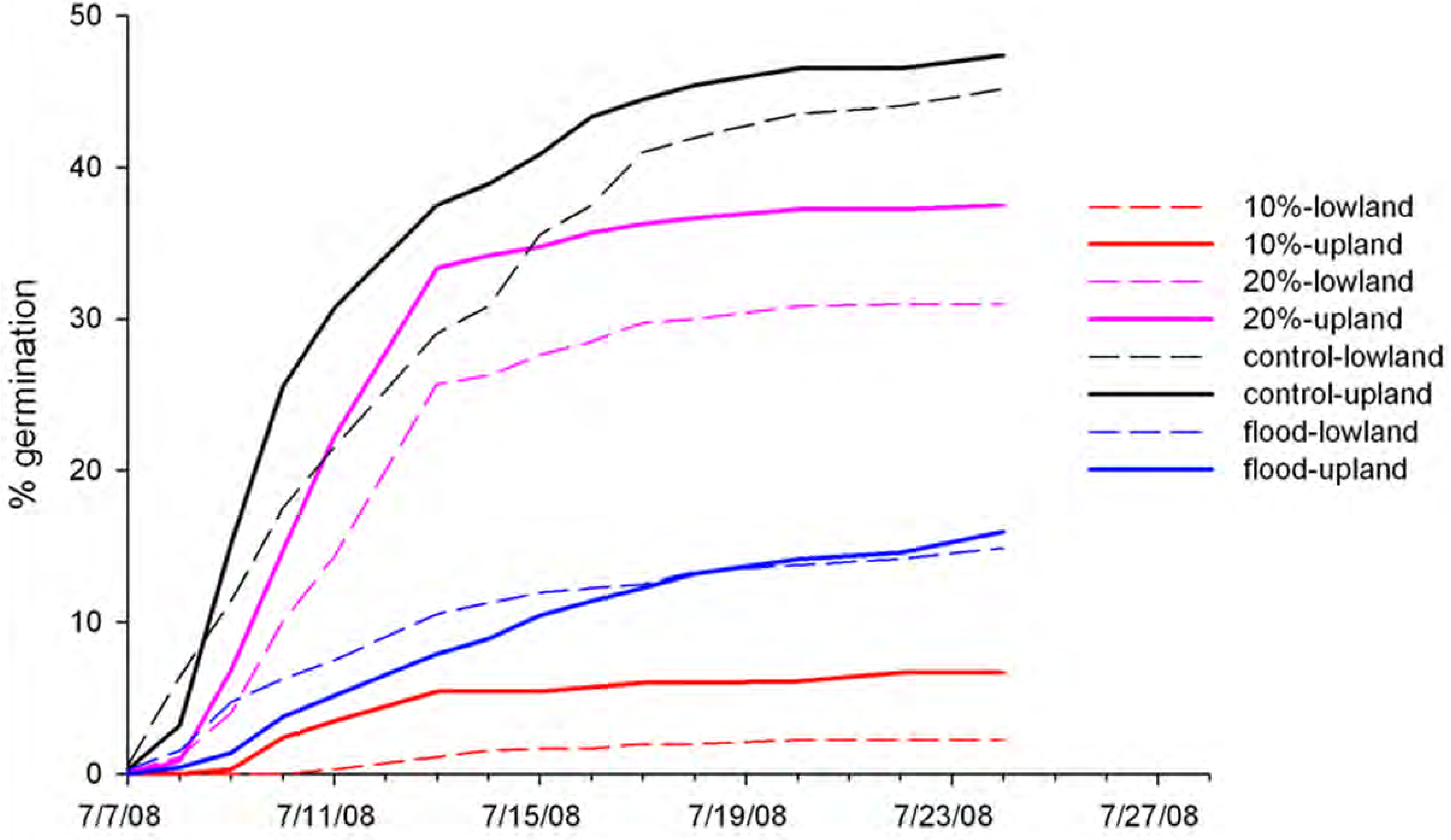


Control

Flooded
root zone

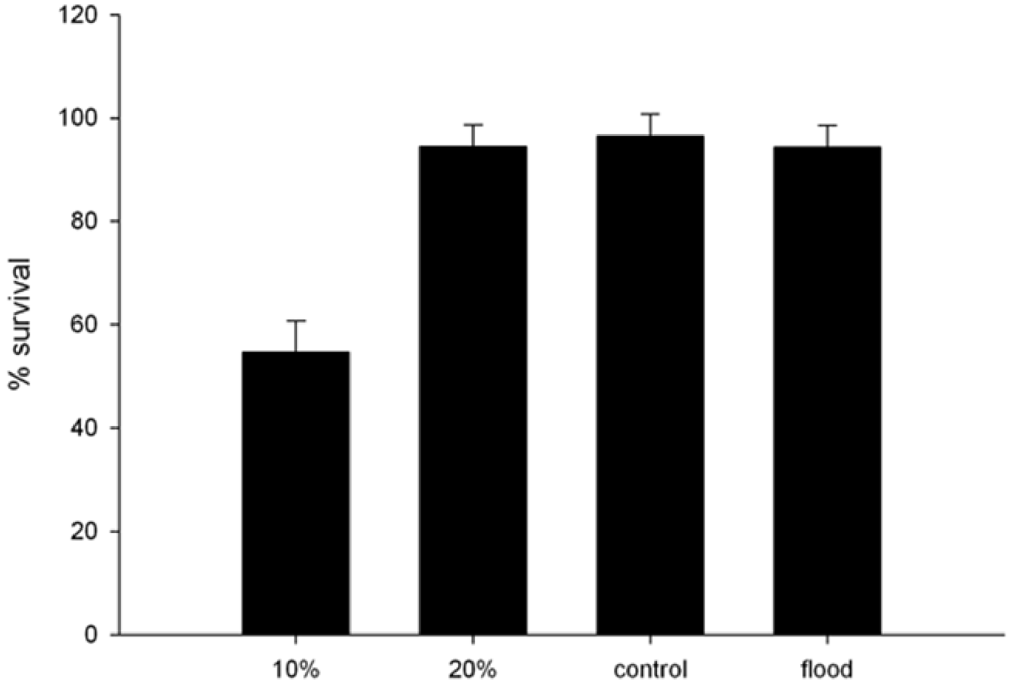
Drought
(-4 MPa)

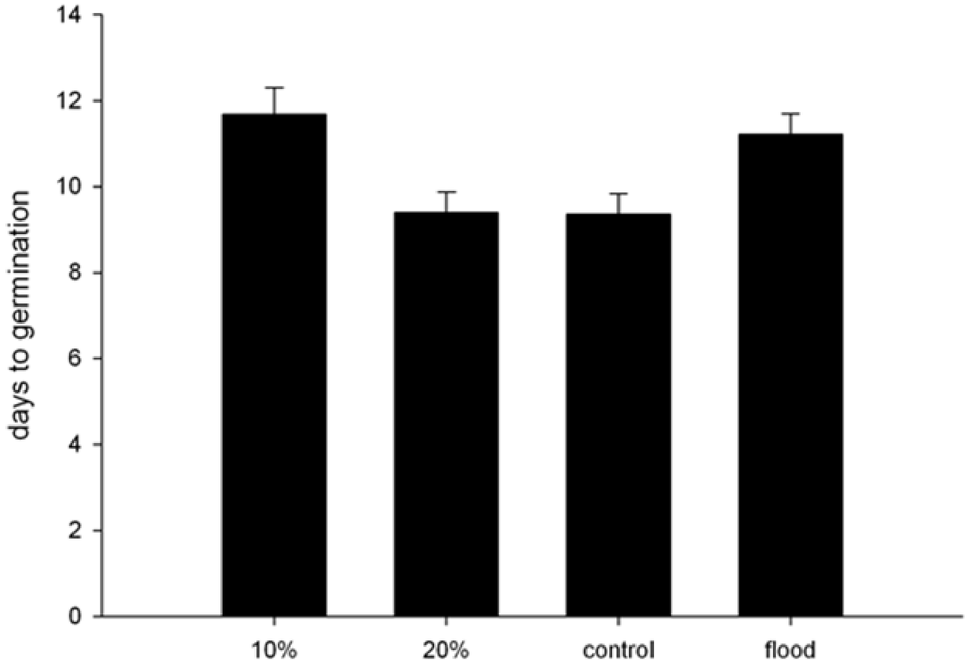
Barney et al. *In Press*



Barney et al. *In Press*

Ecological characters





Barney et al. *In Press*

Germination characters

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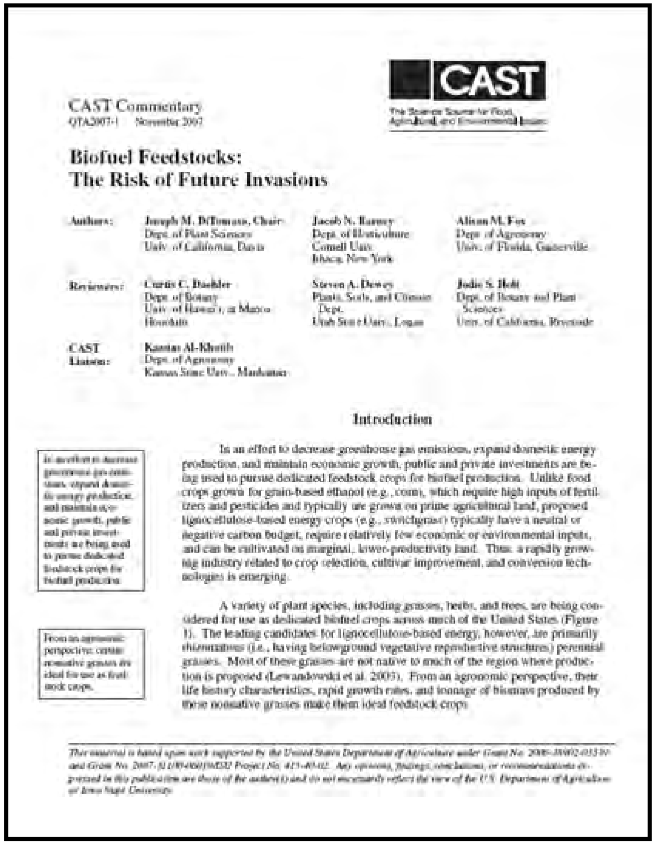

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From an agronomic perspective, certain nonnative grasses are ideal for use as feedstock crops.

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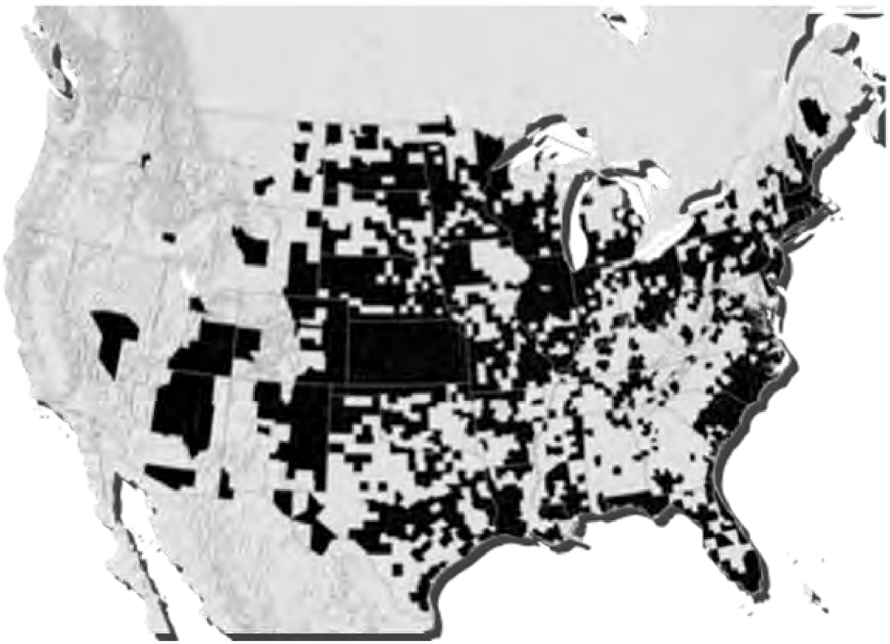
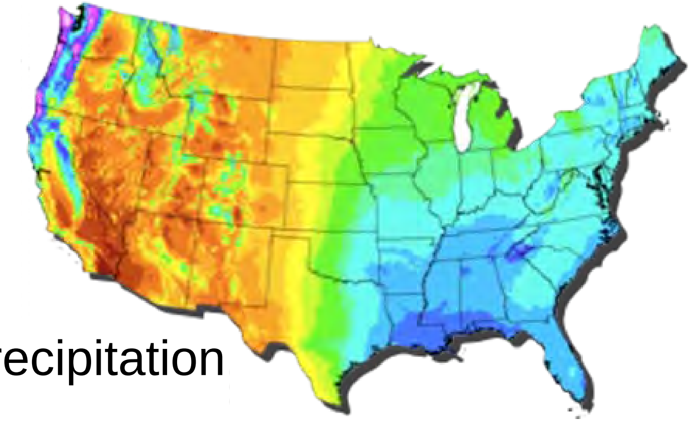
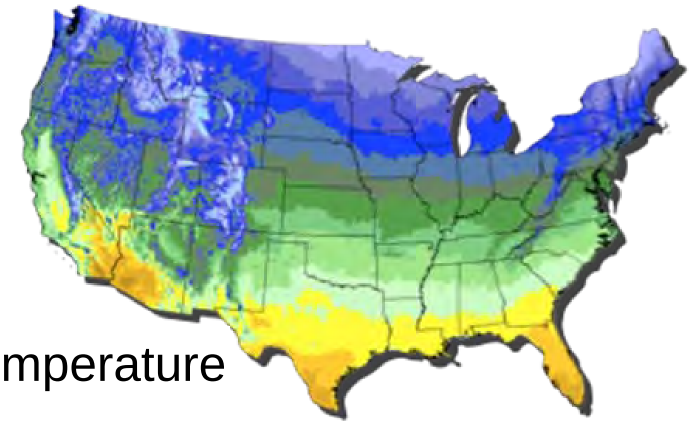
What is the potential range?

Climate-matching

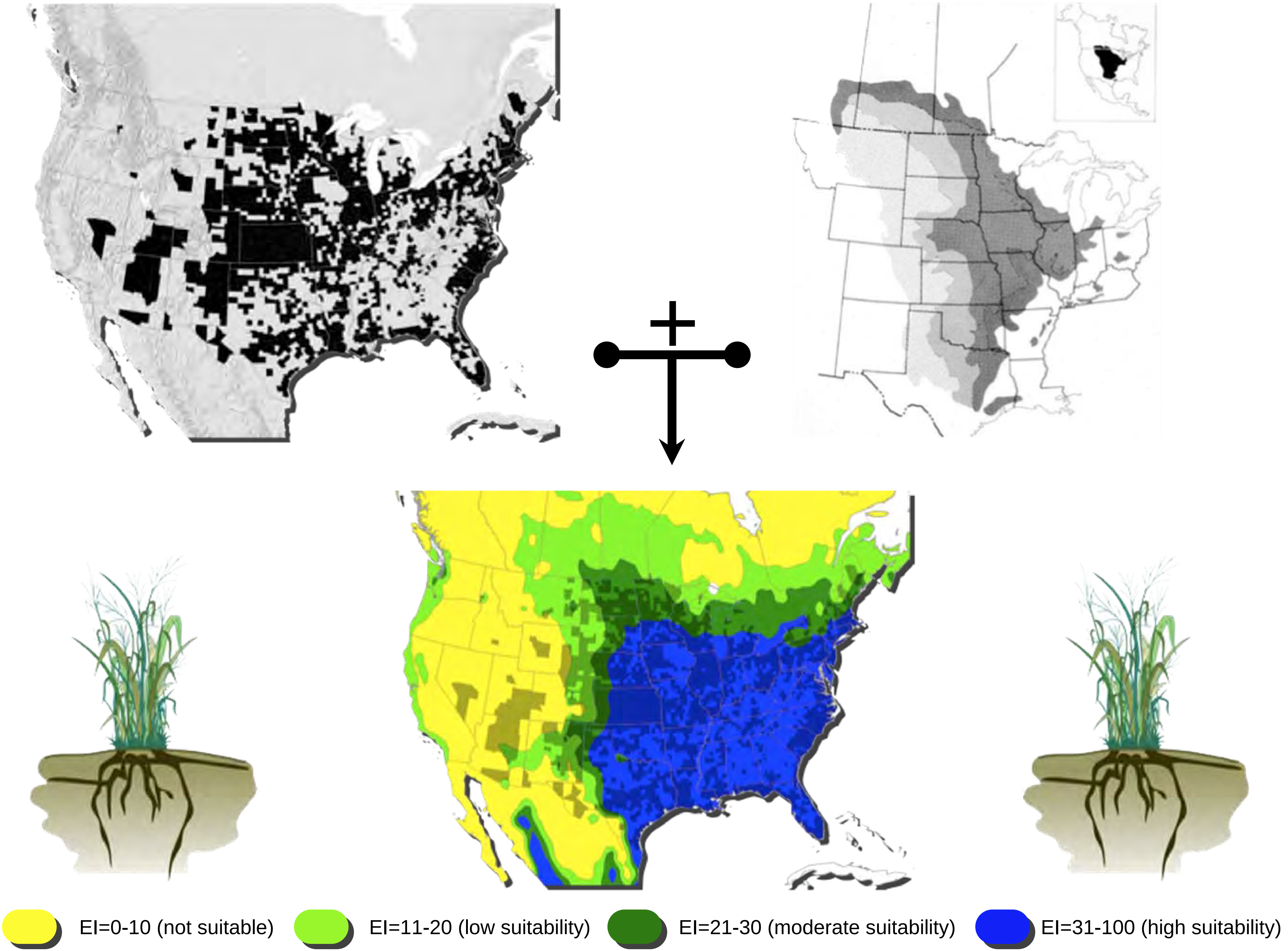




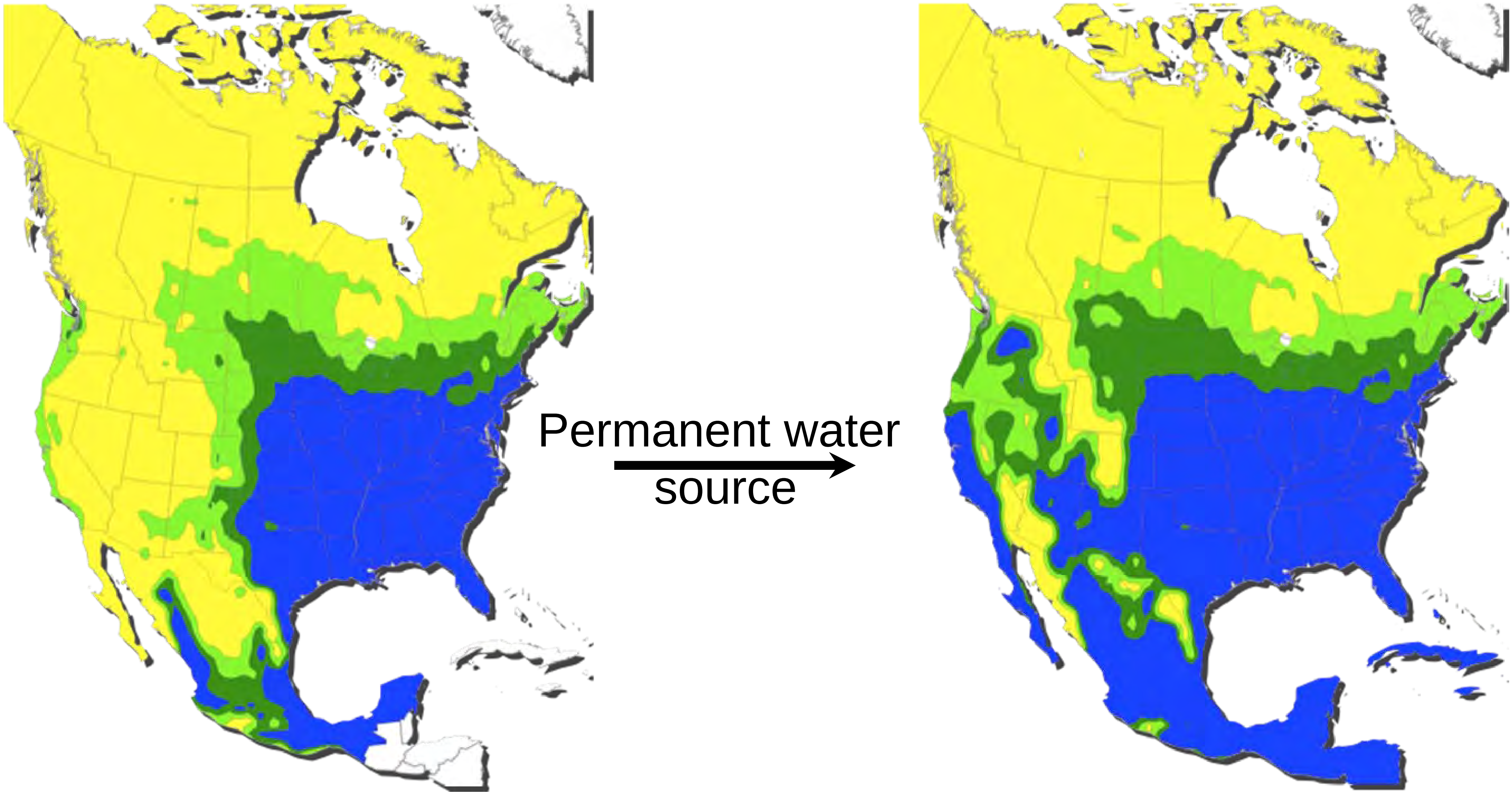
precipitation



temperature


EI=0-10 (not suitable)
EI=11-20 (low suitability)
EI=21-30 (moderate suitability)
EI=31-100 (high suitability)

What is the potential range? CLIMEX



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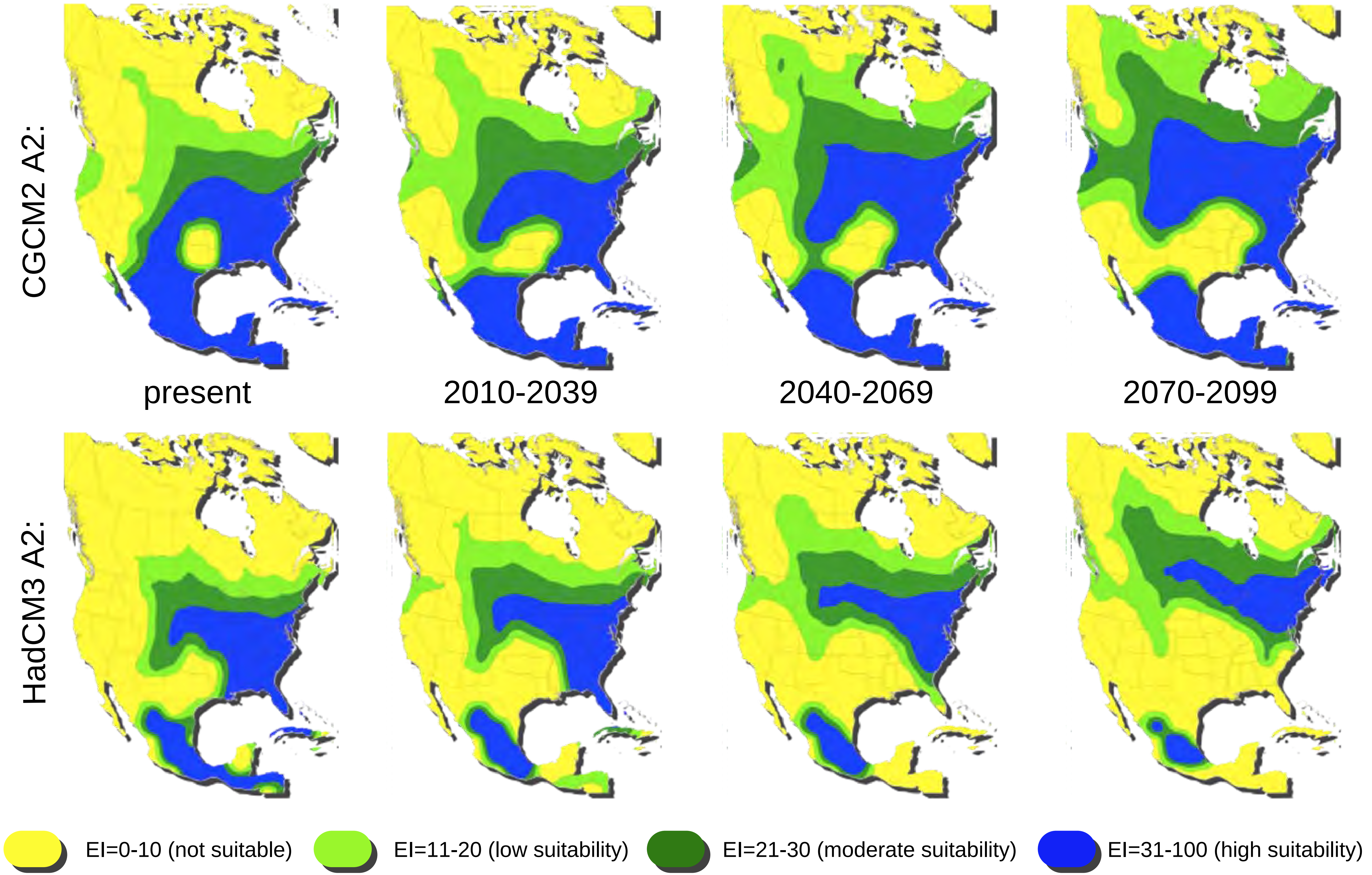
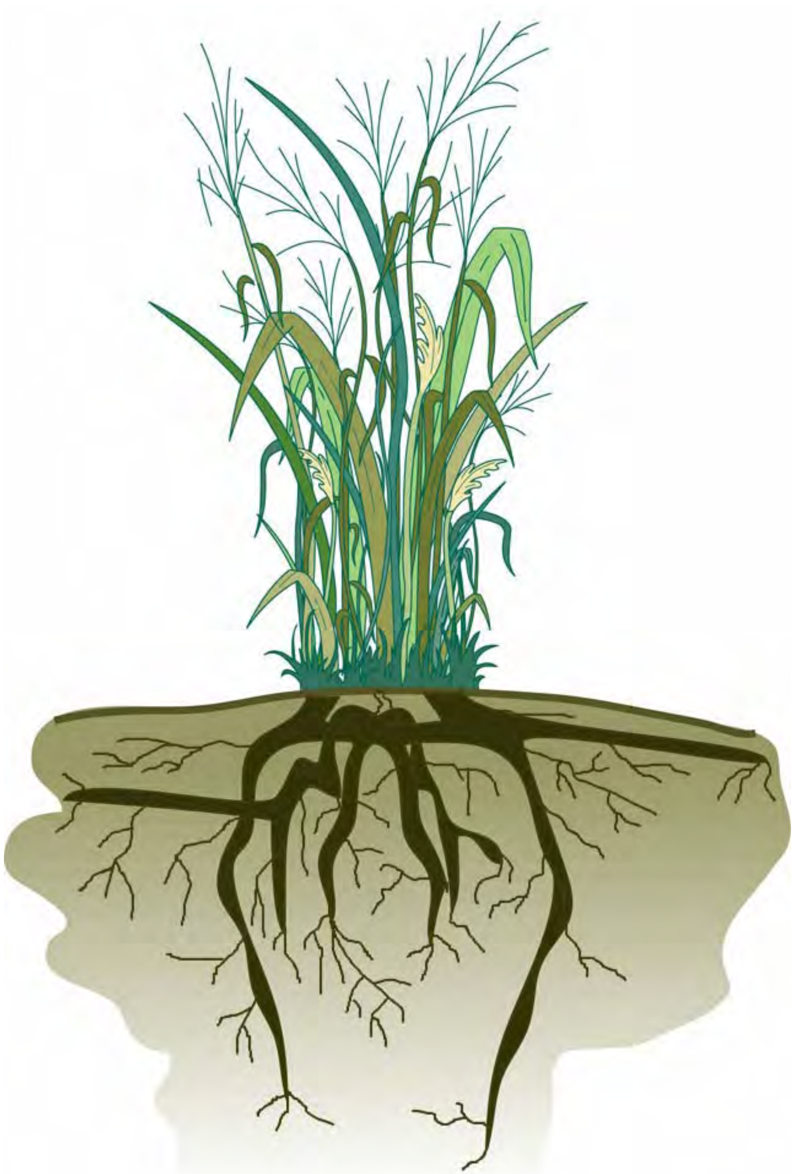
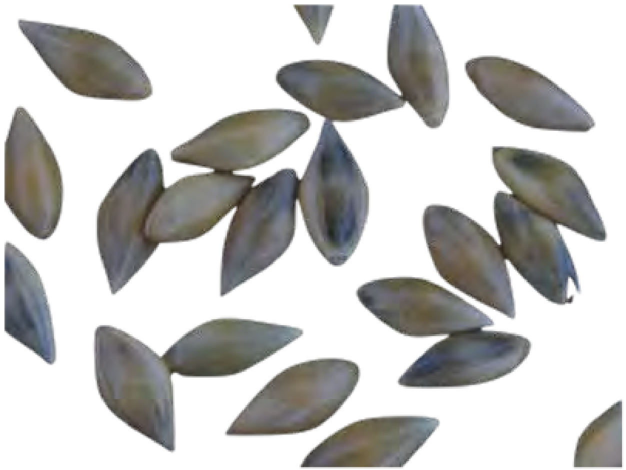
Climate change models: CLIMEX



Propagules: seeds, stems/rhizome fragments





Disseminule survival: stem fragments

1. size, water content
2. burial survival
3. age, phenology
4. sheath impedance

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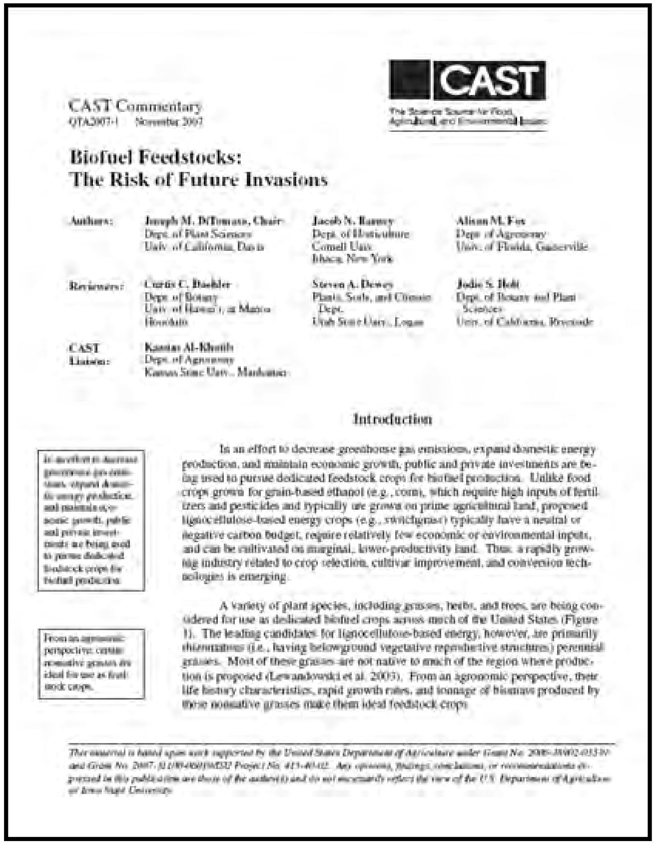
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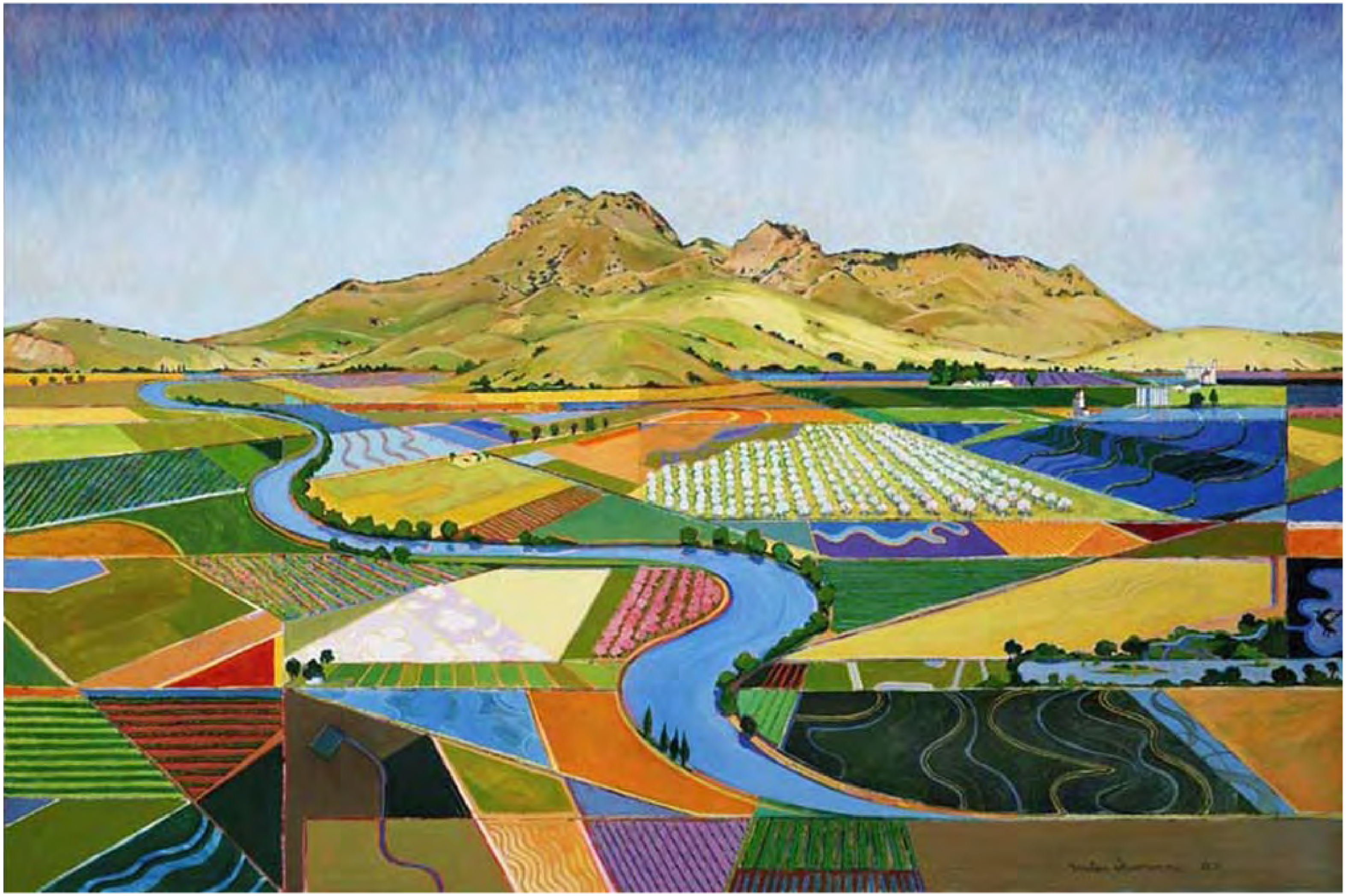
Introduction

In an effort to decrease greenhouse gas emissions, expand domestic energy production, and maintain economic growth, public and private investments are being used to pursue dedicated feedstock crops for biofuel production. Unlike food crops grown for grain-based ethanol (e.g., corn), which require high inputs of fertilizers and pesticides and typically are grown on prime agricultural land, proposed lignocellulose-based energy crops (e.g., switchgrass) typically have a neutral or negative carbon budget, require relatively few economic or environmental inputs, and can be cultivated on marginal, lower-productivity land. Thus, a rapidly growing industry related to crop selection, cultivar improvement, and conversion technologies is emerging.

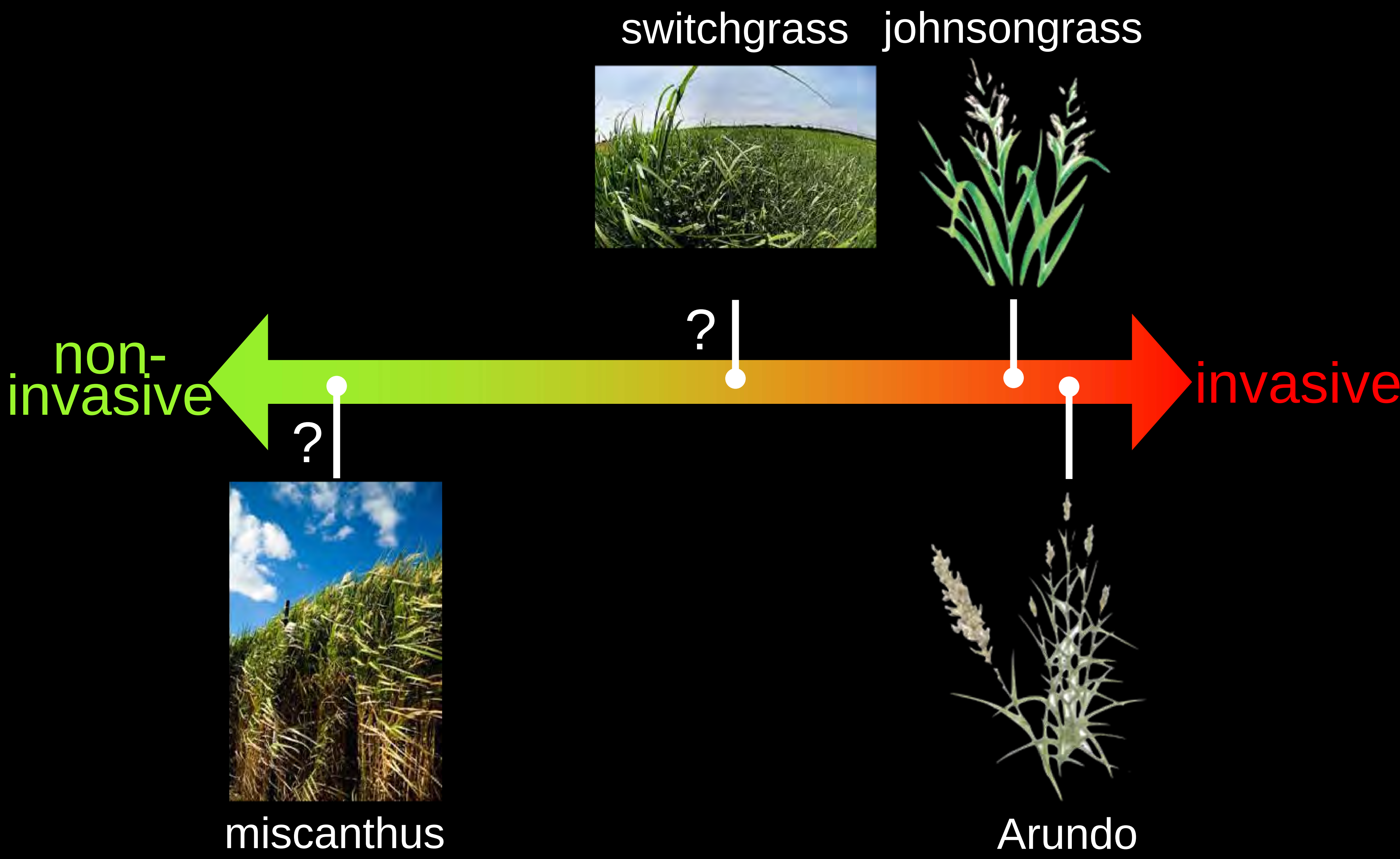
A variety of plant species, including grasses, herbs, and trees, are being considered for use as dedicated biofuel crops across much of the United States (Figure 1). The leading candidates for lignocellulose-based energy, however, are primarily rhizomatous (i.e., having belowground vegetative reproductive structures) perennial grasses. Most of these grasses are not native to much of the region where production is proposed (Lewandowski et al. 2003). From an agronomic perspective, their life history characteristics, rapid growth rates, and tonnage of biomass produced by these nonnative grasses make them ideal feedstock crops.

Ecological analyses: field studies



Ecological analyses: field studies

Ecological analyses: competition



Biofuel Feedstocks: The Risk of Future Invasions

Recommended Actions:

- Emphasize cultivar/genotype-by-region evaluations
- Weed Risk Assessment
- Environmental tolerance
- Climate-matching analyses
- Evaluation of cross-hybridization potential
- Identify susceptible ecosystems (natural and managed)
- Quantify impacts of biofuel crop escape into ecosystems
- **Incorporate information from ecological studies into breeding programs, agronomic models, and risk analysis to mitigate invasions**
- Establish pre-commercial management protocols

CAST Commentary
QTA2007-1 November 2007

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Mitigation

- Identify invasive characters and minimize via breeding/engineering/selection
- Cultivate in a landscape context
- Scout field borders, propagule corridors
- Minimize propagule escape via harvest, storage, transportation management

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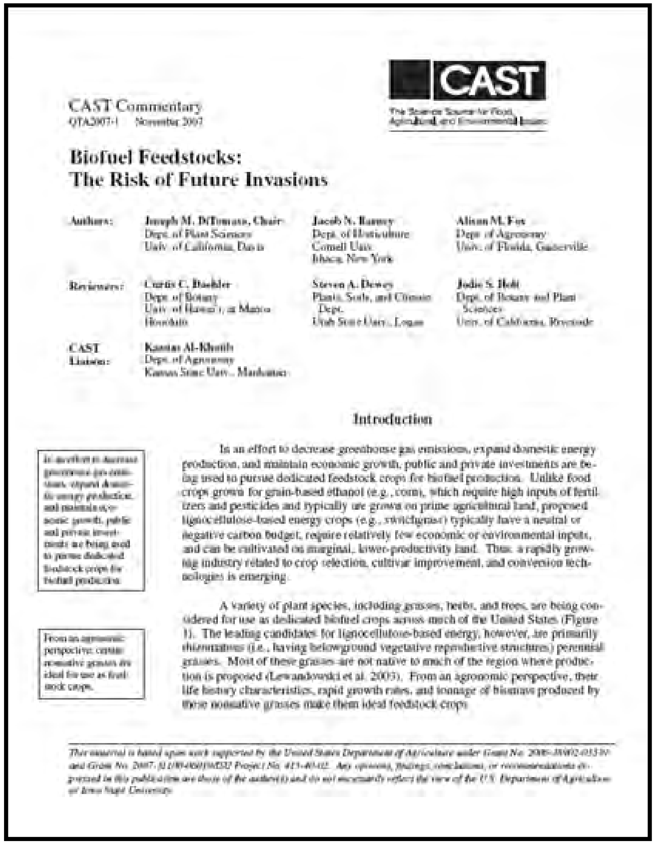
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Introduction

How do we prevent cultivating the next invasive species?

- Risk assessment
- Climate-matching analysis
- Cross-hybridization potential
- Escape potential
  - Seed / rhizome / stem / auto-fragment
- Ecological analyses
  - Disturbance tolerance
  - Community invasibility
- Create eradication plan
- Mitigation via breeding/engineering, cultivation in landscape context, scouting, harvest management

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